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MMORPGS and cognitive performance: A study with 1280 Brazilian high school students

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ABSTRACT

The present paper attempts to empirically study the cognitive impacts of Massive Multiplayer Online Role-Playing Games (MMORPGs) in uncontrolled contexts in light of the Cognitive Mediation Networks Theory, a new model of human intelligence that aims to explain cognition as the result of brain activity combined with the information-processing done by external structures such as tools, social groups and culture. A sample of 1280 students Brazilian high school students answered a form inquiring about socio-demographic information plus the use of computer games, and also was submitted to a short knowledge exam and a mini psychometric test. The findings indicated that, due to their underlying structure and sociocultural nature, MMORPGs are associated to a greater level of insertion into the Digital Age, higher levels of logical-numerical performance, and better scholastic ability. Finally, suggestions are made for future studies on the subject.

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1. Introduction

Computer games arose in the second half of the 20th Century, starting with Noughts and Crosses, created in 1952 by A. S. Douglas of Cambridge University, and the first domestic game, called Odyssey, was launched in 1972 by Magnavox (The Video Game Revolution, 2007). In 1975 the first role-playing games (RPGs) were implemented on a computer, initially using only text and, later on, with graphic user interfaces, along with the Multi-User Domains (MUDs) that allowed for multiple players to interact through Bulletin Board Services and the Internet (Barton, 2007a, 2007b, 2007c). This paved the way for the emergence of the Massive Online Role-Playing Games (MMORPGs), that is to say, role-playing games where a large number of players simultaneously interact within a single, persistent, online virtual world. This type of computer game came into evidence in the late 1990's with Ultima Online and EverQuest, Lineage and others, but has recently experienced an enormous growth, particularly in the case of the World of Warcraft, which boasts the impressive figure of over 10 million players acquired in a little over three years of existence (Blizzard, 2008; Schiesel, 2006).

Given the growing demographics and cultural significance of the MMORPGs, there has been a growing body of research involv-

ing this genre of game, particularly in the fields of psychology, sociology, economics, and computing (Azevedo, 2007a, 2007b; Gilsdorf, 2007).

Many of the studies have concentrated on the social dynamics of the game and the implications it has for the players. Generally, it is found that MMORPGs involve complex forms of interaction and collaboration that often translate into improved social skills and activity in real life (Axelsson & Regan, 2002; Duchenaud & Moore, 2005; Heckel, 2003; Oliver, 2002; Whang, 2003; Williams et al., 2006; Wing, 2007). Inversely, a few have observed that collective organization and trade in the virtual world closely mimic entrepreneurship, finance and economics in actual life (Dodson, 2006; Lehdonvirta, 2007). From an emotional and motivational perspective, some authors have found that the social and cultural aspects of the MMORPGs are the main incentive to play, leading to positive feelings and strong bonding between players (Chen, Duh, Puah, & Lam, 2006; Cole & Griffiths, 2007).

A significant portion of the research has also focused on the cognitive processes involved in MMORPGs. Some address the description of the gaming activity itself, such as player-character interactions (Fine, 1983; Tychsen et al., 2005), player-game interactions (Apargyis & Poulymenakou, 2005; Lindley, 2002; Song, Lee, & Jo, 2007; Takatalo, 2006), and the acquisition of expertise (Apargyis & Poulymenakou, 2005; Song & Lee, 2006). Others deal more directly with the underlying mental phenomena, such as spatial and sensory motor skills (Green & Bavelier, 2004), conceptual blending (Thomas & Brown, 2007), scientific thinking (Steinkuehler & Chmiel, 2006), and cognitive overload (Anga, Zaphiris, & Mahmooda, 2007).

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In spite of all the literature regarding MMORPGs, however, one is hard-pressed to find investigations regarding the impacts of naturalistic, uncontrolled, gaming on the cognitive performance of the individual player in non-gaming settings. Most of what is published in this regard is actually based on deduction and inference originated from the investigations of social and psychological processes in gaming rather than on direct evidence of the impact of games on mental ability. Also, most of the studies on video games in general tend to use them as tools or scenarios under which psychological phenomena can be investigated, rather than as objects of interest *per se* (Rebetez & Betrancourt, 2007).

The present paper attempts to help overcome the gap in the literature on the impacts of MMORPGs not only by means of a relatively direct, large-scale, empirical investigation, but also with the aid of a novel perspective on human intelligence called the Cognitive Mediation Networks Theory, a new model which attempts to explain cognitive development, functioning and performance as the result of the information-processing done by the brain supplemented by the information-processing done by external structures such as instruments, social groups and cultural interactions, which would function as computational devices. The success of the model not only in explaining the interaction between individuals, collectives, and tools, but also in describing and predicting the impacts of digital technologies on cognitive processes and performance, make it a natural candidate for the theoretical framework from which to contemplate the investigation in question (Campello de Souza, 2006; Campello de Souza & Roazzi, 2006, 2007).

2. The cognitive mediation networks theory

2.1. Fundamentals

In spite of the relevance of the subject and of the debate around it, the collective and individual cognitive impacts of the digital revolution is something that is not satisfactorily explained by traditional theories of human cognition (Papadakis & Collins, 2001; Tapscott, 1998). Regarding video games in particular, one finds a similar situation, as pointed out by Rebetez and Betrancourt (2007) who reviewed the specialized literature on the subject and pointed out that most of the research on the subject focus on cognitive abilities and skills, affective and motivational aspects, knowledge and content learning, but does so from the perspective of using these games as promising tools or scenarios under which such psychological phenomena could be studied, with no intention of considering the games themselves or their cognitive impacts as scientific objects of interest.

The Cognitive Mediation Networks Theory is a contextualist, constructivist, information-processing approach that aims to provide contributions to help overcome this gap in the literature, drawing from the previous concepts and research from various authors, such as Jean Piaget, Gérard Vergnaud, and Lev Semenovich Vygotsky, and attempting to create a coherent theoretical synthesis of their ideas (Campello de Souza, 2006; Campello de Souza & Roazzi, 2006, 2007).

The basic concept of the Cognitive Mediation Networks Theory is that cognition is the result of information-processing (Chalmers, 1999; Kail & Bisanz, 1992; Sternberg, 1988), with the human brain being finite and not altogether satisfactory in terms of raw computational power (Merkle, 1988, 1989; Miller, 1956; White, 2003), so that human beings are driven to use external structures in the environment for supplementary computing, including not only physical objects and artefacts, but also things such as social groups and cultures, all of which would function as auxiliary computational devices (Campello de Souza, 2006).

Such use of external information-processing aids, which may be termed “extra-cerebral cognition” or simply “mediation”, is possible due to the fact that any system with some degree of regularity in its dynamics is capable of functioning as a Turing Machine, that is to say, as a computational device (Copeland & Sylvan, 1998). Such a system may be a tool or machine, as in the case of paper and pencil, calculators and computers, but it can also be a social or cultural group governed by specific rules for behaviour and interaction (Campello de Souza, 2006).

In order to integrate the information-processing done by the brain and the one executed by external mechanisms, it is necessary that there be some logical link between these computational devices, in other words, some way of translating inputs, outputs, and throughputs between them. This is very similar to having to install a “device driver” software in a computer system so that it can recognize and deploy a specific piece of external hardware, such as a printer, a scanner or an external storage device. In humans, this may be achieved by means of a mental representation of a physical system that is comprised of a set of “theorems-in-action”, in the sense established by the Theory of Conceptual Fields (Vergnaud, 1997), that are analogous to the dynamic functioning of the said external mechanism, therefore, making it possible for an individual to interact with it for information-processing purposes. As such, the development of this “internal mechanism” occurs by means of the interaction between the individual and the corresponding physical system, that is to say, through the process described in the Genetic Epistemology as “equilibration” (Piaget, 1990; Seminério, 1996; Campello de Souza, 2006).

As it is described here, the process of mediation produces the obvious advantage of allowing an individual to significantly enhance his or her computational capacity (and, therefore, cognitive powers) by a distributed processing between the brain and its external aids. However, the possibility of deploying various types of complex and sophisticated “cognitive prosthesis” is not the only implication. Indeed, one may also conclude that, given the nature of the mental representations (theorems-in-action), their mere existence endows the individual with a set of logical tools that enhances his or her competence in specific domains even in the absence of the corresponding external physical system. Thus, an individual’s patterns of thinking, that is to say, his or her logical approaches, strategies, competences and reasoning, are, to a significant extent, defined by the mediation mechanisms formed by means of a personal history of interaction with different kinds of social groups, tools, instruments, and other cultural elements, very much as predicted in socio-constructivist theories (Luria, 1976; Vygotsky, 1998; Campello de Souza, 2006).

In essence, the Cognitive Mediation Networks Theory can be described a new contextualized information-processing theory of human cognition that integrates the fundamental concepts of some of the most important theories in cognitive psychology, such as Piaget’s Genetic Epistemology (equilibration), Vergnaud’s Theory of Conceptual Fields (theorems-in-action), and Vygotsky’s Socio-Constructivism (the roles of society and culture), into a single, unified, coherent, model (Campello de Souza, 2006).

2.2. Hyperculture

With the introduction of the personal computer in 1975, of the World Wide Web in 1991, and of Windows 95 in 1995, amongst many other developments, the World began what has been called by many the “Digital revolution” or the “Digital Age” (Julian, 1996; Keller & Kumar, 1999). In the relatively short time span of 20 years, a series of related technologies emerged that, together, lead to enormous transformations in societies and cultures all over the planet, forever changing economics, politics, legislation, mores, and even individual values, beliefs, and habits (Tapscott, 1998, 2003).

Currently, an individual who lives in a society that is experiencing the Digital Age is required to learn, acquire, and/or develop a complex set of sophisticated skills in order to deal with several tasks and tools that are now “mandatory”, such as:

- Choosing, installing, operating, and/or managing specific components of hardware, software, and/or networks;
- Understand and make use of new abstract concepts such as “interactivity”, “interface”, “hypertext”, and “virtual”;
- Dealing with interpersonal interactions through a plethora of electronic devices and networks within the context of new forms of online social organization.

According to the Cognitive Mediation Networks Theory, the Digital Revolution has provided society with new contents, structures, and dynamics, thereby effectively creating new potential external information-processing mechanisms and, consequently, by means of interaction, also a new internal mechanisms. Specifically, the new tools, concepts, values, practices, and socio-cultural habits of the Digital Age tend to be embedded with the logic inherent to the technology underlying such revolution, that is to say, to the formal and mathematical thinking underlying the workings of computers and of the Internet. This amounts to saying that the Digital Age is associated to a new way of thinking, a novel form of mediation that, for being an expanded version of a “culture”, may be called “hyperculture” (Campello de Souza & Roazzi, 2006; Campello de Souza, 2007).

The initial empirical investigations regarding the cognitive impacts of the advent a hyperculture seem to confirm the theoretical expectations that there is a new set of emergent socio-cultural variables regarding the interaction with digital technologies that seem to be a clearly distinct facet from that of the more traditional socio-cultural variables (Campello de Souza & Roazzi, 2007). Furthermore, it has been found (Campello de Souza, 2006; Campello de Souza & Roazzi, 2006) that the interaction with digital technologies is associated to new forms of thinking (preference for visual mental representations and for dealing with problems involving quantitative contents, greater use of IT-related metaphors) that are indeed related to the underlying logic or contents of such tool, leading to different patterns of cognitive development (earlier onset of growth in raw psychometric scores, later slowing of growth in test scores, higher score upon which development “levels off”), as well as to significant distinctions in the cognitive functioning of digital and pre-digital generations (members of the “digital generation”, along with having greater familiarity with technology, are more prone to preferring visual mental representations and to using metaphors with IT).

Given the fact that the emergent internal and external structures add to, and interact with, previously existing ones, it follows that the development of a hyperculture corresponds an evolutionary leap in cognitive evolution. Indeed, there is empirical evidence that regular use of digital tools and the immersion into hypercultural practices is clearly associated to higher levels of cognitive performance as measured by psychometric tests, scholastic achievement, the authoring of scientific papers, and self-evaluations, an effect observable even when one controls for the possibly confounding effects of sex, age, income and schooling (Campello de Souza, 2006; Campello de Souza & Roazzi, 2006, 2007).

3. Hyperculture and gaming

3.1. Gaming in the digital age

The advent of computers and telecommunications in the Digital Age changed the gaming world by introducing the possibility of devices with four important capabilities:

- Automation of repetitive gaming mechanics, such as dice-throwing, calculation, positioning of players within a board or map, maintenance of records, and so forth;
- Rich audiovisual representations synchronized with in-game events, including pictures, animations, movies, sounds, voice, and music;
- Artificial intelligence capable of generating complex interactive virtual worlds, that is to say, environments and elements that influence a player and are influenced by him or her according to a predefined set of rules and dynamic properties;
- Long-distance interactions between the players and the game and between the players themselves.

Whether occurring by means of dedicated gaming machines or by gaming software installed on a general-purpose personal computer, the capabilities brought by digital technologies lead to the emergence of three distinct types of “computer games”, namely, stand alone games, local network games, and Massive Multiplayer Online Role-Playing Games (MMORPGs), the later being a variety where thousands of players or more play simultaneously in the same game world, which is maintained independently of the users (which is why they are also called “persistent worlds”), and where each participant constructs a relatively detailed avatar through which he or she will interact with other players and with the virtual world (Yee, 2006).

Each type of game tends towards a specific social functioning and game play dynamics. The Stand Alone variety is essentially void of direct social interaction, though user and fan groups may be formed around them. Local Network Games allow for direct interaction, but such interactions tend to be brief and limited, which is why this type of game is usually very fast-paced and combat-oriented. MMORPGs, on the other hand, allow for richer, complex, long-term, social interactions, and are usually oriented towards strategy more than tactics, and, very much unlike what usually happens in their offline counterparts, they add the possibility of direct competitive interactions between players, such as combats or duels.

3.2. Cognitive mediation in MMORPGs

Role-Playing Games are essentially sophisticated systems of play where the situational context, be it historical wars, fantasy worlds, the supernatural or fantastic realities, is less relevant than the complex mathematical rules that govern play, particularly in the case of MMORPGs. It is the assimilation and internalization of such rules that makes it possible for a player to indeed be a part of an abstract world, along with other fellow players, and to interact with them and with that world in meaningful ways.

According to the Cognitive Mediation Theory, for such an assimilation/internalization to happen, one must enter the socio-cultural circle of players, with its specific jargon, concepts, values, habits, tools and forms of interaction, which, together, will serve as a set of auxiliary information-processing devices, that is to say, as cultural external mediation mechanisms. That, in turn, requires from the individual the construction of internal mediation mechanisms made up of concepts, schemes and competences whose underlying logic is akin to the underlying logic of the game. Eventually, the internal mechanisms become an intrinsic part of the individual, providing him or her with an additional set of intellectual tools that can be deployed even in the absence of the corresponding external mediation Mechanisms. Given the fundamental characteristics of the game, the external mechanisms and their internal counterparts tend to be comprised of concepts and schemes whose underlying operative invariants are strongly abstract, logical and mathematical in nature.

In the particular case of MMORPGs, not only the inherent logical and mathematical nature of the game comes into play, but also the hypercultural characteristics of the digital mediation as whole. In light of the Cognitive Mediation Theory, such a combination clearly points towards the fostering of logical and mathematical abilities, particularly (but not exclusively) when involving children and adolescents, all of which would yield a significant boost in cognitive performance, with relevant impacts on psychometric scores, scholastic achievement, and even scientific production.

4. Method

4.1. Objectives

The purpose of the present study was to investigate the use of MMORPGs among the middle-to-upper-class adolescents that comprise the Digital Generation and the cognitive impacts of that use. Specifically, the aim was to:

- Estimate the prevalence of the use MMORPGs among high school adolescents in comparison to the use of other forms of digital technology;
- Characterize the profile of the typical MMORPG player in contrast to their non-playing peers;
- Attempt to infer some of the impacts of the use of MMORPGs on the performance of human cognition.

The fundamental intention is to test some of the predictions of the Cognitive Mediation Theory with regards to MMORPGs, specifically, that the engagement in such games is positively associated to higher level of psychometric ability, particularly logical and numerical skills, and, therefore, also to scholastic performance.

4.2. Participants

A total of 1280 students of both sexes enrolled in the last grade of high school education from a list of 23 high profile private institutions in the Metropolitan Area of Recife, Pernambuco, Brazil, during the 1st semester of 2006;

4.3. Materials

One form containing 89 items (distributed into 33 questions) regarding the socio-demographic profile of the participant, his or her experiences, behaviours and attitudes towards school, and time spent using different forms of digital technologies.

One Knowledge Test containing 10 simple “true” or “false” questions in high school mathematics, physics, chemistry, biology, history, geography, Portuguese, and English, out of which three scores can be calculated:

- *Logical Score*: Number of correct answers in mathematics, physics and chemistry;
- *Taxonomical Score*: Number of correct answers in biology, history, geography, Portuguese and English;
- *Overall Knowledge Score*: Total number of correct answers out of all the test questions.

One Psychometric Test containing a total of five questions involving different kinds of tasks and contents (mental reversal of image, geometric knowledge and visualization, word analogy, kinetics, and mathematics), out of which three scores can be calculated:

- *Numerical Score*: Number of correct answers in the problems involving calculations in kinetics and mathematics;
- *Verbal Score*: Number of correct answers in the verbally presented problems involving descriptions and word analogies;
- *Overall Psychometric Score*: Total number of correct answers out of all the test questions.

4.4. Procedures

4.4.1. Preparation of the experimenters

The experimenters were a total of 65 students enrolled in Statistics 101 from the Universidade Federal de Pernambuco, from the undergraduate programs in Business Administration and Executive Secretariat, and also from the graduate program in Production Engineering, all of which were oriented, through both oral and written instructions, to:

- Collect the data from subjects with the desired socio-demographic profile;
- Avoid having personal friends and relatives as research subjects;
- Be polite and have good manners;
- Use plain language and make themselves understood;
- Obtain answers to all of the questions in the form;
- Obtain answers in the format indicated in the form;
- Not influence the content of the answers obtained.

The interviewers were also informed that the data collected by each individual researcher would be statistically compared to the bulk of the data from the remaining researchers in order to detect and eliminate eventual outliers, which would implicate in the failure of the task by the student, in which case there would be negative implications in that student's grade in Statistics 101. Such a procedure was indeed executed after all the data was collected, two outliers found and their data removed from the sample.

4.4.2. Interactions with participants

All the participants were individually approached by the experimenters in the schools and streets of the metropolitan area of Recife and, after a brief description of the study and a generic overview of its goals, they were asked to cooperate with the investigation.

Upon a clear manifestation of willingness to participate in the study, each individual was then submitted to, in order:

1. A verbal interview, with no time constraints, using the research form (usually taking close to 30 min to complete);
2. A verbal presentation of the Knowledge Test, with 10 s being given for each question, after which the experimenter registered a correct response as a “1” and an incorrect response or inability to supply an answer as a “0”, the total test lasting a little over 100 s;
3. A verbal presentation of the Psychometric Mini-Test, with 10 s being given for each question, after which the experimenter registered a correct response as a “1” and an incorrect response or inability to supply an answer as a “0”, the total test lasting a little over 60 s.

All of the responses to the form and to both tests were registered by the interviewer on a previously prepared printed data sheet.

In spite of the varied open and public settings, each individual was taken aside in order to, within the possibilities of the locations, avoid the direct proximity of third parties, and care was taken to minimally assure freedom from noise and other possible sources of interruption.

4.4.3. Comments

The procedure adopted here was aimed at assessing the desired population in both a practical and effective manner, with care being taken so as to assure, within the research goals, a reasonably varied and well-measured sample. The questionnaire and tests were specifically designed to allow for easy and relatively fast applications.

The settings in which the data was collected were not ideal for direct “absolute” measurements of psychological traits in a traditional sense, though this would impact more the precision than the validity of such measurements. However, the fact that all of the subjects were assessed in the same fashion and compared to one another (instead as to a standardized group that took the tests while sitting down and using paper and pencil, like in a traditional IQ test) makes it quite adequate to use such measurements to detect associations between these variables and other individual traits, as was the case.

4.5. Statistical analysis

The data that collected in the present investigation was submitted to statistical analysis comprising of descriptive (mean, standard deviation, min–max, percentages) and inferential (hypothesis tests, ANOVA, regression models) statistics. Regarding the later, parametric and non-parametric techniques were used according to the numerical scale of the variables analyzed (dichotomous, ordinal, or continuous) and their probability distribution (Gaussian or non-Gaussian).

5. Results

5.1. Profile of the sample

5.1.1. Sex, age and perceived socioeconomic status

The sample obtained consisted of 1280 participants, being 622 (48.6%) male and 658 (51.4%) female, with an average of 17.4 years of age ($SD = 0.94$), ranging individually from 14.8 years up to 25.5 years.

Approximately 50.2% declared to perceive their economic life-style as “Very Good” or “Comfortable”, 39.7% as “Average”, and 10.1% as “Modest” or “Struggling”.

5.1.2. Access to and use of digital technology

Out of the total number of students that were interviewed, approximately 87.9% had access to a computer and 83.7% had access to the Internet at home, while 28.5% had access to a computer and 22.4% to the Internet at their school. Respectively 90.8% had access to a computer at home or at school and 87.0% had access to the Internet in at least one of those places.

More than half of the subjects made regular use of search engines (91.1%), e-mail (87.3%), online chat software (81.3%), digital imaging hardware and software (61.8%), and text editors (54.0%). Grouping all kinds of use into three broad types, one has:

- **Communication:** Imaging technology, e-mail, website editing, blogs, and/or online chats;
- **Work and Study:** Text editor, electronic spreadsheet, and/or study-oriented Web searches;
- **Games:** Simple offline games (e.g., Tetris, Minesweep, Solitaire), complex offline games (e.g., Tomb Raider), online “shooter” games (e.g., Counterstrike), and/or MMORPGs (e.g., World of Warcraft).

Table 1 shows the use of digital technologies among the students interviewed.

There was a statistically significant difference on the Student's t Test for Independent Samples between the fractions of students using each type of technology, that is to say, Work and Study vs. Communication ($t = 13.965$ and $p < .01$), Communication vs. Games ($t = 28.496$ and $p < .01$), and Work and Study vs. Games ($t = 15.771$ and $p < .01$), as well as between the amounts of time spent using them (Chi Sqr. = 1408.262 $p < .01$ on the Friedman ANOVA).

5.2. Computer gaming

Table 2 shows the use of computer games among the students interviewed categorized per type of game.

Out of those who declared to play MMORPGs, approximately 89.5% dedicated 10 h/week or less to the game, and only 2.1% dedicated more than 20 h.

About 53.0% of the adolescents declared to play offline games of some sort, versus 24.5% who declared engaging into online games, a statistically significant difference (Student $t = 19.367$, $p < .01$).

5.3. Demographics of the MMORPG players

Approximately 74.7% of the students who declared to play MMORPGs were male, versus 44.3% among the non-players, a statistically significant difference (Student $t = 7.788$, $p < .01$).

The students who declared to play MMORPGs were, on average, 17.64 years old ($SD = 1.290$) and those who did not had an average age of 17.35 years ($SD = 0.866$), a small, but statistically significant, difference (Mann–Whitney U test with $z = -2.316$ and $p = .02$). In particular, there was a higher proportion of RPG players 18 years old or older (23.2%) than among non-players (15.2%), a statistically significant difference (Student $t = -2.701$, $p < .01$).

The observed differences regarding perceived economic life-style, measured on a 1–5 Likert scale, between players (average = 3.46, $SD = 0.740$) and non-players (average = 3.44, $SD = 0.758$) were not statistically significant (Mann–Whitney U test with $z = -0.291$ and $p = .77$).

There were also no statistically significant differences between players and non-players of MMORPGs regarding their access to computers at home (respectively, 88.5% vs. 87.8%, $t = -0.255$, $p = .80$), to the Internet at home (respectively, 84.1% vs. 83.6%, $t = -0.155$, $p = .88$), to computers at school (respectively, 31.3% vs. 28.1%, $t = -0.094$, $p = .37$) and to the Internet at school (respectively, 21.4% vs. 22.6%, $t = 0.347$, $p = .73$).

5.4. Interaction with technology for players and non-players

Table 3 shows the comparison between players and non-players of MMORPGs with regards to the amount of time they spend using different sorts of digital technology.

The MMORPG players spent significantly more time using all sorts of digital technology, save only for e-mail and online chatting, where they did not differ from non-players.

5.5. Reliability and validity of the cognitive tests

Considering all the items of both the Knowledge and the Psychometric Tests at once, in order to overcome the small number of items of each individual test (total of $10 + 5 = 15$ items), therefore relying on the semantic similarity between the constructs of psychometric intelligence and scholastic knowledge, one obtains a fairly good level of reliability (Cronbach Alpha = .69).

The Knowledge Test presented a positive and statistically significant correlation with school performance (Spearman Rho = .27, $p < .01$), time spent studying (Spearman Rho = .28, $p < .01$), and, to lesser degree, with the Psychometric Test (Spearman Rho = .18, $p < .01$) and with the time spent on extracurricular reading

Table 1

The use of computer digital technologies among the students.

Type of technology	Proportion of students using	Hours per week spent using			
		Average	SD	Min	Max
Work and study	82.1%	4.72	4.710	1	48
Communication	95.9%	17.51	17.036	1	146
Games	56.6%	7.05	9.151	1	86

Table 2

The use of computer games among the students.

Type of game	Proportion of students who play	Hours per week spent playing			
		Average	SD	Min	Max
Simple offline games	36.6%	2.62	2.822	1	30
Complex offline games	35.9%	4.29	4.824	1	42
Online “shooter” games	19.7%	3.93	4.768	1	42
MMORPGs	14.2%	5.07	5.622	1	42

Table 3

Comparison of the interaction with technology between players and non-players of MMORPGs.

Amount of interaction (h/week)	Players (n = 182)		Non-players (n = 1098)		Mann–Whitney U test	
	Average	SD	Average	SD	z	p
Word processor	1.9	2.53	1.3	2.12	−4.25	<.01
Electronic spreadsheet	0.6	1.39	0.4	1.42	−4.83	<.01
Digital photography and image editing	2.4	3.01	2.0	2.89	−2.28	0.02
Simple offline games	1.5	2.51	0.9	2.04	−4.86	<.01
Complex offline games	3.9	5.12	1.1	3.04	−14.06	<.01
E-mail	3.8	6.40	3.0	3.78	−1.24	0.21
Web searching for school activities	2.4	2.91	2.1	2.42	−2.13	0.03
Web searching for personal activities	4.3	5.60	3.1	3.68	−3.24	<.01
Creating or maintaining websites	1.3	3.37	0.6	2.38	−5.01	<.01
Writing/updating blogs	2.1	4.51	1.5	3.44	−2.99	<.01
Online chats	5.8	6.88	6.2	7.41	−0.39	0.70
Online “Shooter” games	2.8	4.59	0.4	1.95	−17.17	<.01

(Spearman Rho = .13, $p < .01$). The Psychometric Test, in turn, was shown to have a positive and statistically significant correlation with self evaluations of intelligence (Spearman Rho = .15, $p < .01$), verbal ability (Spearman Rho = .08, $p < .01$), visual aptitude (Spearman Rho = .12, $p < .01$), and numerical skills (Spearman Rho = .14, $p < .01$), as well as with school performance and with the Knowledge Test, as mentioned before. Such associations are consistent with what would be expected of the constructs of psychometric intelligence and scholastic knowledge, being indicative of the validity of the instruments used.

5.6. Cognitive performance of players and non-players

Table 4 shows the comparison between players and non-players of MMORPGs with regards to Scholastic Achievement, the Knowledge Test and the Psychometric Test.

The MMORPG players did not show any significant difference to their peers regarding their overall Scholastic achievement, but did have a statistically higher level of Scholastic Achievement per Hours of Study (7% more).

On the Knowledge Test, the MMORPG players had statistically superior results on the Logical Score (8% more), but not on the Taxonomical or the Overall Scores.

On the Psychometric Test, the MMORPG players had significantly better results on the Numerical (29% more) and Overall (12% more) Scores, but not on the Verbal Score.

5.7. Logistic regression analysis of logical and numerical performance

Adding the Logical and Numerical scores, one obtains an index that ranges from zero to eight that measures the combined logical and mathematical performance. Table 5, below, shows a logistic regression analysis model that attempts to predict the occurrence of higher levels of such a score (“higher”) defined as results that are equal to or greater than the median).

The above model was obtained after testing combinations of all the independent variables that were measured, including sex, age and access to computers and the Internet, but including only those with a p -value (Wald Chi²) of .05 or less for their association with the dependant variable.

Though the regression model that was arrived at has a fairly low level of specificity, it does serve the purpose of establishing associations between the independent variables and the dependent variable in a way that: (a) removes or minimizes the effects of the covariance, (b) estimates the relative impact of each predictive variable, and (c) determines the joint predictive power of the variables studies, allowing one to assess the amount of variation yet to be explained.

Fig. 1 plots the percentage of participants with a high Logical–Numerical scores versus the time spent playing MMORPGs.

The diagram clearly illustrates the trend towards a monotonic growth in the chance of a high score as the students spend more time playing online role-playing games.

Table 4

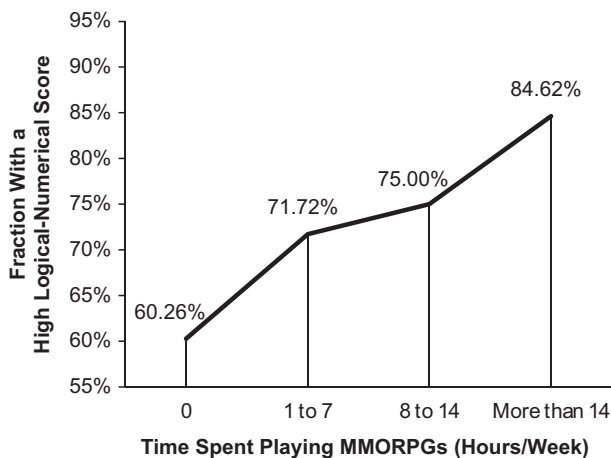
Comparison of the cognitive performance between players and non-players of MMORPGs.

Type of performance	Players (n = 182)		Non-Players (n = 1098)		Mann–Whitney U test	
	Average	SD	Average	SD	z	p
Scholastic achievement	6.88	1.349	6.84	1.409	−0.547	0.58
Scholastic achievement/Hours of study	1.18	1.031	1.10	1.197	−2.521	0.01
Knowledge test	Logical score (0–6)	3.81	3.54	1.324	−2.754	0.01
	Taxonomical score (0–4)	2.86	2.93	0.976	0.677	0.50
	Overall score (0–10)	6.67	6.46	1.745	−1.598	0.11
Psychometric test	Verbal score (0–3)	1.66	1.56	0.829	−1.520	0.13
	Numerical score (0–2)	0.67	0.52	0.680	−2.336	0.02
	Overall score (0–5)	2.33	2.08	1.132	−2.250	0.02

Table 5

Logistic regression model for higher (>4) or lower (<4) scores on the Logical-Numerical items on the Knowledge and Psychometric Tests.

Variables	Estimate	Odds-ratio	Wald Chi ² (p)
Time spent playing MMORPGs	0.06	13.57	0.03
Taste for logical subject matters	0.36	4.15	<.01
Time spent in extracurricular reading	0.04	4.07	0.02
Time spent studying	0.02	3.06	<.01
Preference for visual mental images	0.28	1.32	0.02
Appraisal for the quality of the classes at school	−0.17	0.51	0.04
Constant	−0.48		
Chi ² (6) = 69.600 p < .01; Odds-ratio = 2.16			
Estimation method: Quasi-Newton			
Sensitivity = 88.4%; Specificity = 22.1%;			
Positive predictive value = 65.0%; Negative predictive value = 53.8%			

**Fig. 1.** Time spent playing MMORPGs versus probability of a high logical-numerical score.

6. Discussion

6.1. Computer gaming in the digital generation

As it seems to be the case throughout most of the urban industrial societies of the western world, the middle and upper class adolescents investigated here are highly involved with the use of digital technologies in general. Close to 90% had direct access to computers and the Internet, more than 95% were making regular use of communication tools such as e-mail, Internet messaging and online forums, and more than 80% were using text editors and electronic spreadsheets to do schoolwork. These are the sort of findings that have inspired the media to dub teenagers with these demographics the “digital generation”.

Computer gaming is usually considered to be a prevalent form of activity among the members of the so-called digital generation, and, indeed, one or more varieties of it was found in more than half of the subjects. It is important to observe, though, that the proportion of those who engaged in any kind of digital gaming (57%) was far more modest than that of those who used communication resources (96%) or work tools (82%). Furthermore, for these subjects, communication activities took up more than twice the time games did (18 vs. 7 h/week). Therefore, it appears that, at least within the group that was investigated, in spite of the widespread access to, and use of, digital tools, playing computer games is far from being the norm or even the most prevalent type of use of IT.

6.2. MMORPG players as a minority

Even though a little over half of the adolescents interviewed declared to play some sort of computer game (57%) and almost all of them used the Internet for communication purposes (96%), the use of offline games (53%) was found to be more than twice as prevalent as the online ones (25%). Also, among those who played online games, there were more playing online “shooter” games than playing online RPGs (20% vs. 14%). This makes it quite obvious that MMORPG players are definitely a small minority even within the relatively tech-savvy members of the digital generation.

Such a finding is consistent with the fact that, as a large-scale social phenomena, MMORPGs are a very recent development in modern society, with barely a decade having gone by since the emergence of Ultima Online and Everquest, and less than four years since the launching of World of Warcraft, the first title to actually reach beyond a small niche of players and go into the mainstream. Indeed, to this day, World of Warcraft still has more players than the sum of the players of all the other titles taken together. Therefore, it comes as no surprise that one still only finds approximately only one out of every seven middleclass adolescent students playing the genre, particularly in a developing country

like Brazil, which still lacks significantly in several aspects of its infrastructure.

6.3. Profile of the MMORPG player

6.3.1. Sex and age

In comparison to their peers, the online RPG players were more frequently male (75% vs. 44%), perhaps reflecting the overall tendency of a masculine majority in most technology-oriented activities ranging from entertainment to profession. That being the case, the same explanations regarding sociocultural traditions, roles, and preferences, along with possible differences in thinking, would apply in the present situation. One can speculate that most games include contents and activities that are inherently male-oriented, or maybe this type of gaming activity itself is not considered “appropriate” for females in Northeastern Brazil. Either way, there is clearly a sex-based bias to be observed.

Regarding age, the MMORPG players tend to be slightly older than the non-players (17.6 vs. 17.4 years of age), with a higher proportion of 18 year-olds or older (23% vs. 15%). Given that 18 years of age or more is considered to be older than the norm for students in the last year of high school in Brazil, this may be an indication that such students were held back sometime in the past and/or that they were schooled a little later than usual. But this could also simply be a statistical consequence of the fact that the mean age of MMORPG players tends to be significantly higher than that of the usual high school student. Anyhow, it seems safe to say that there is also an age-related selection bias associated to the game.

6.3.2. SES and digital inclusion

With no relevant differences in perceived standard of living or in access to computers and to the Internet, it seems that any cognitive differences displayed by the gamers are not due to their income or to exposure to IT in general. Therefore, a digital divide of a purely socioeconomic nature cannot be evoked to explain the differences between players and non-players of MMORPGs in the population studied.

6.3.3. Hyperculture

Even though they had no privileged access to computers or the Internet, nor any sign of a more favourable SES, the MMORPGs players, in comparison to their peers, spent more time using all kinds of digital tools for work and play, and just as much time using e-mail and chat. Given that this group of subjects is a small minority defined by their engagement in a very recent type of gaming technology, a genre reputed by many pundits as being the spearhead of the development of the IT industry (i.e., the user interface of the future and the very essence of the interactive Web), it is fair to infer that these players have a significantly greater level of identification with the hyperculture than their non-player peers.

6.4. Games, digital technologies and cognitive functioning

The MMORPG players were more efficient in terms of the grades obtained for every hour of study invested (7% advantage). Such students also scored higher on the Logical (8% better) and, especially, the Numerical (29% more) items on the tests that they took. Regarding the remaining Taxonomical and Verbal scores, the players were no different than their peers.

The cognitive advantages of the MMORPG players in comparison to the non-players cannot be explained by their specific demographics, given that:

- There were no differences between players and non-players regarding perceived SES and the access to digital technologies;

- Though there were differences in sex and age, these variables did not play an independent role in the combined logical and numerical index according to the logistic regression analysis;
- The time spent playing MMORPGs was the individual variable that showed the strongest association to the combined logical and numerical index in the logistic regression analysis.

Strictly speaking, the present study design does not allow for the determination of direction of causality or even of causality itself, so that it is not possible to differentiate whether the results found here indicate an actual impact of games on cognition or simply a selection bias where individuals with certain cognitive advantages tend to be more attracted to MMORPGs. However, given the observed demographic differences players and non-players of the type of game, such a bias would suggest some sort of association between age, sex, and cognition, but that has been practically ruled out by the results of the regression analysis. Furthermore, psychometric and scholastic abilities are, to a significant degree, explainable by schooling and socioeconomic status, both of which were essentially identical in the two groups compared.

Weighing all the evidence, there seem to be relatively strong arguments in favour of the existence of an actual effect of gaming on cognition rather than the opposite, that is to say, these findings point strongly towards a *per se* association between playing MMORPGs and improved logical and numerical skills. Furthermore, it seems that such an association is more relevant than most of the other variables that one would consider when trying to explain the performance in tasks involving formal and abstract knowledge, things such as motivation, educational experiences, mental representations, and so on.

These combined findings are in full accordance with the predictions of the Cognitive Mediation Networks Theory regarding MMORPGs, from which one clearly expects the scientific and mathematical nature of both RPGs and the hypercultural mediation to specifically require of those who engage in them the development of logical and numerical abilities.

7. Conclusions

It seems that, even in a developing country such as Brazil, there is currently, at least within a specific social stratum, a Digital Generation that presents an almost ubiquitous deployment of digital technologies, perhaps not unlike what one can find in more developed nations. Such use tends to focus primarily on communication, though deployments for work and study are also extremely common.

Computer gaming as a whole was shown to be fairly frequent among the segment of teens that was studied, but not nearly as much as digital communication or the use of digital technologies for work and study. The engagement in online games was even more modest. In the particular case of the MMORPGs, only a relatively small minority of students was involved, most of which male and slightly older than their peers, but with no signs of having any difference regarding SES or access to computers or the Internet. This is suggestive of the existence of some sort of socio-cultural selection bias, but one that is not as simplistic as education, level of income or the digital divide.

MMORPG players tend to be more hypercultural than their non-playing peers, engaging more not only in games in general but also in the use of almost every type of digital technology. This is accompanied by evidence of superior logical and mathematical skills, along with greater efficiency in terms of school performance. Such a set of cognitive advantages was shown to not only be independent of the specific demography of the players, but also primarily

associated to the time spent playing. Thus, it appears that the present investigation has produced evidence to corroborate the predictions of the Cognitive Mediation Theory that engagement in MMORPGs tends to lead teenage players to develop complex internal mechanisms that provide them with improved logical and mathematical capabilities. As expected, such an effect appears to be specific to that particular type of game, primarily because of the peculiar nature of its rules and dynamics.

The bulk of the present findings suggest the possibility that MMORPGs could be used not only as a viable teaching tool, but also as a parallel activity that could function as a significant “catalyst” for education. On a broader scale, they might indeed be the “spearhead” of the current status of the “Digital Revolution”, bringing with them an early glimpse of the concomitant cognitive evolution. Such possibilities, however, require further investigation.

Future studies on the cognitive aspects of MMORPGs should attempt to detail the internal and external mediation mechanisms adopted by players, their impacts on game play and satisfaction, as well as the role of motivations and emotions in the dynamics of the psychology of gaming. In other words, further investigations regarding the impacts of these games on human cognition require one to observe internal psychological processes as well as external socio-cultural phenomena, plus the interaction between these two spheres.

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